Occupational Cancer Among Women: Where Have We Been and Where Are We Going?

Shelia Hoar Zahm, ScD* **and Aaron Blair,** PhD

Studies of occupational exposures have been a fruitful area of research for identifying carcinogens. Some of the early observations, such as increased risk of breast cancer among nuns and bone cancer among radium dial workers, were made among women. Recent research on cancer among women has shown increased risks of cancer in many industries and occupations. Estimates that 1% of cancer among women is attributable to occupation are based on research conducted mainly in the 1970s among men in developed countries. These studies do not reflect the dramatic changes in the participation of women in the workplace or the patterns of employment of women in developing countries. The proportion of women in the paid workforce, the amounts and types of unpaid labor, the distribution of women by economy sector, the scale of the workplaces, the allowable exposure levels in the workplace, and implementation of controls have changed over time and vary internationally. Occupational cancer researchers need to expand their focus on women, increase activities in developing countries, include newly created industries, use sophisticated exposure assessment methods, and, where appropriate, incorporate molecular epidemiologic techniques to discover new occupational carcinogens and to identify where better control measures are needed. Am. J. Ind. Med. 44:565–575, 2003. *Published 2003 Wiley-Liss, Inc.*†

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INTRODUCTION

Work should be a place where people provide a living for themselves and their families, a place of accomplishment, and a place of satisfaction, not a place where women increase their risk of disease and injury for themselves or their family members. Identifying and controlling hazardous occupational exposures should be a public health priority, particularly because these are involuntary exposures from the workers' perspective, yet these exposures are largely preventable (Table I). Society can and should ensure that harmful occupational exposures are identified and reduced.

Despite these principles, occupational research until recently focused mainly on men. In 1993, the first international conference on occupational cancer among women was held in Baltimore, Maryland, to publicize and rectify this situation. A survey of 1,233 epidemiologic papers on occupational cancer published between 1971 and 1990 revealed that only 14% presented any analysis of results on white women and 2% on nonwhite women [Zahm et al., 1994]. Only 7% of the papers had detailed results for white women and 1% for nonwhite women. Befitting this lack of research on women, most of presentations at that first conference in 1993 were reviews, general surveys, and record linkage studies [Pottern et al., 1994]. Few analytic studies with original gender-specific data were presented.

Little improvement in the inclusion of women was evident in a more recent review of the populations studied by the Research Institute on Occupational Health and Safety of

Division of Cancer Epidemiology and Genetics, National Cancer Institute, NIH, DHHS, Rockville, Maryland

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*Correspondence to: Shelia Hoar Zahm, Division of Cancer Epidemiology and Genetics, National Cancer Institute, NIH, DHHS, 6120 Executive Blvd., EPS 8074, Rockville, MD 20892-7242. E-mail: zahms@mail.nih.gov

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TABLE I. Classification of Occupational Exposures and Selected Risk Factors by Their Voluntary Nature and Prevention Potential

	Involuntary	Voluntary
Preventable	Occupational exposures	Tobacco use
Not preventable	Genetic susceptibility	Some reproductive factors[a]

[a] While some reproductive factors, such as pregnancy may be considered voluntary, related factors, such as age at first birth, cannot be considered "preventable" and it is highly unlikely that women alter their age at first birth to modify cancer risk.

Québec, Canada in 1999 [Messing, 2002]. Although 45% of the labor force in Québec consists of women, only 8 of 86 studies included populations with more than 33% women.

A second international conference on occupational cancer among women was held in Reykjavík, Iceland, in 1998 [Gunnarsdottir et al., 1999]. The conference was expanded to include reproductive risks [Lindbohm, 1999], more European scientists participated, and more analytic studies were presented. Some important findings on occupational cancer were reported, such as the observation that occupational exposures were responsible for a sizable fraction of lung cancer among non-smoking women in Europe [Boffetta et al., 1998; Jahn et al., 1999]; the possible role of solvents in the etiology of breast cancer [Hansen, 1999] and renal cancer [Dosemeci et al., 1999]; excesses of melanoma, bladder cancer, and leukemia among female agricultural workers in Italy [Settimi et al., 1999; Sperati et al., 1999]; and increased risks of esophageal, stomach, and ovarian cancer among women exposed to benzene, asbestos-contaminated talc fillers, and other exposures in the Russian printing industry [Bulbulyan et al., 1999].

Barcelona, Spain, was the setting for the third conference in this series, held September 13, 2002. Scientists from North America, Western Europe, Eastern Europe, Asia, Middle East, Central and South America, and Africa participated. There appears to be progress because several large studies with state-of-the-art exposure assessment and molecular epidemiology components were described. It is important to report these results and continue to make the case for efforts in this area.

WHY STUDY OCCUPATIONAL CANCER AMONG WOMEN?

Studies of Occupational Exposures Have Been a Fruitful Area of Research for Identifying Carcinogens

Over half of the agents classified by the International Agency for Research on Cancer as known, probable, or possible human carcinogens are primarily occupational exposures. Some of the earliest classic observations, such as increased risk of breast cancer among nuns [Ramazzini, 1700] and bone cancer among radium dial workers [Adams and Brues, 1980; Stebbings et al., 1984], were made among women. There are still numerous leads regarding occupational carcinogens that require evaluation. Some of these require focus on women.

More recent research has shown increased risk of leukemia among women exposed to benzene [Yin et al., 1987; Li et al., 1994], other solvents [Giles et al., 1984; Morton and Marjanovic, 1984; Oleske et al., 1985; Walrath et al., 1985; Bulbulyan et al., 1992; Burnett and Dosemeci, 1994; Anttila et al., 1995], vinyl chloride [Smulevich et al., 1988], antineoplastic drugs [Skov et al., 1992; Lynge, 1994], radiation [Wang et al., 1988], and pesticides [Giles et al., 1984; Ronco et al., 1992; Blair et al., 1993; Linet et al., 1994], or employed in food processing [Morton and Marjanovic, 1984; Bulbulyan et al., 1992], or the textile and garment industries [Stayner et al., 1985; Aronson and Howe, 1994; Linet et al., 1994]. Elevated lung cancer rates have been observed among women exposed to asbestos [Newhouse et al., 1972; Acheson et al., 1982; Wignall and Fox, 1982; Newhouse et al., 1985; Botta et al., 1991; Brownson et al., 1993; Brown et al., 1994; Dement et al., 1994; Rösler et al., 1994] and metals [Menck et al., 1977; Lubin and Blot, 1984; Olsen and Jensen, 1987; Park et al., 1988; Kato et al., 1990; Wu-Williams et al., 1990, 1993; Merler et al., 1994; Rubin et al., 1994; Blot and Fraumeni, 1996; Carpenter and Roman, 1999], including arsenic, chromium, nickel, and mercury, as well as among women employed in motor vehicle manufacturing [Wu-Williams et al., 1993; Aronson and Howe, 1994; Delzell et al., 1994; Beall et al., 1995; Wang et al., 1995], food service [Menck et al., 1977; Olsen and Jensen, 1987; Dimich-Ward et al., 1988; Bulbulyan et al., 1992; Burnett and Dosemeci, 1994; Kjaerheim and Andersen, 1994; Rubin et al., 1994; Carpenter and Roman, 1999], or cosmetology [Menck et al., 1977; Milne et al., 1983; Skov et al., 1990; Pukkala et al., 1992; Rubin et al., 1994]. Bladder cancer is excessive among women employed in the dyestuff and textile [Delzell and Grufferman, 1983; Maffi and Vineis, 1986; Gonzalez et al., 1989; Silverman et al., 1990; You et al., 1990; Zheng et al., 1992; Cordier et al., 1993; Bulbulyan et al., 1995; Carpenter and Roman, 1999], rubber and plastic [Silverman et al., 1990; Zheng et al., 1992; Solionova and Smulevich, 1993; Swanson and Burns, 1995; Carpenter and Roman, 1999], and leather industries [Decoufle, 1979; Garabrant and Wegman, 1984], as well as among painters [Silverman et al., 1989], dry cleaners [Katz and Jowett, 1981; Blair et al., 1990, 2003], and health care workers [Anthony et al., 1971; Silverman et al., 1989; Levin et al., 1993; Carpenter and Roman, 1999]. Service industries, where many women work, are not necessarily safer than manufacturing and other industries with well recognized hazards [Zahm et al., 2000]. Many other cancers have also been linked to occupational exposures to some degree [Zahm et al., 2000] (Table II).

TABLE II. Selected Industries, Known or Potential Carcinogens, and Reported Cancer Excesses*

Industry	Known/potential carcinogens	Cancers
Service industries		
Health care	Antineoplastic drugs, anesthetic gases, ionizing radiation, viruses	Bladder, brain, breast, leukemia, lung, lymphoma
Cosmetology	Hair dyes, hair sprays, formaldehyde	Bladder, brain, leukemia, lung, lymphoma, ovary
Food service	Tobacco smoke, cooking fumes	Bladder, cervix, esophagus, lung
Dry cleaning	Carbon tetrachloride, trichloroethylene, tetrachloroethylene, other solvents	Bladder, cervix, esophagus, kidney, liver, lung, ovary, pancreas
Manufacturing		
Chemical/plastics/rubber	Vinyl chloride, 1,3-butadiene, benzene, other solvents, nitrosamines	Bladder, brain, breast (?), leukemia, lung, lymphoma, ovary
Textile, apparel	Asbestos, dyes, lubricating oils	Biliary tract, bladder, leukemia, lung, lymphoma, mesothelioma
Motor vehicle manufacturing	Paints, metal fumes, solvents, machining fluids	Colorectum, lung, stomach
Computers, electronics	Solvents, metal fumes	Brain
Furniture	Wood dust, solvents, glues, formaldehyde	Lung, pancreas, sinonasal
Agriculture	Pesticides, sunlight, fuels	Brain, cervix, gallbladder, leukemia, liver, lymphoma, multiple myeloma, ovary, stomach

*From Zahm et al. [2000].

Studies on Men Alone Are Not Sufficient to Describe Risks Among Women

The need for gender-specific occupational cancer research has been identified by Zahm et al. [1994], Blair et al. [1999], and Messing et al. [2003] (Table III). There are hormonal, genetic, and other biological factors that might differentially affect risk among women [Blair et al., 1999; Wizemann and Pardue, 2001; Messing et al., 2003]. Job assignments, tasks within jobs, and use and effectiveness of protective equipment may differ by gender [Messing et al., 1993, 1994; Greenberg and Dement, 1994; Kennedy, 2003]. Risks in some newer industries, which employ many women, such as the semi-conductor industry, have not been fully evaluated for men. In addition, non-occupational factors, such as tobacco use, alcohol consumption, and possible exposures and stress from home responsibilities, that modify occupationally-related risk of cancer may differ by gender [Messing et al., 2003]. Finally, women must be studied to shed light on risks related to gynecological cancer.

TABLE III. Need for Gender-Specific Occupational Cancer Research

- Gender differences in metabolism, genetics, and other biological factors
- Gender differences in jobs and tasks within jobs
- Gender differences in use and effectiveness of protective equipment
- Risk of gynecological cancers cannot be studied among men
- Participation in recently developed industries (e.g., semiconductor industry) not previously studied
- Gender differences in occupational and non-occupational modifying factors

An historical example of the value of studying population subgroups comes from the steel industry [Lloyd et al., 1970; Lloyd, 1971; Zahm and Fraumeni, 1995]. Analyses of all workers combined revealed a slight lung cancer excess; however, analyses by race revealed a striking lung cancer excess among African-American coke oven workers. African-American coke oven workers were more likely to be employed at the top of the ovens, where exposures were greater, than white workers, who worked on the sides of the ovens. The disproportionate job assignments affected their subsequent lung cancer risk. Analyses by gender across various industries and occupations might also lead to important discoveries.

POTENTIAL FOR OCCUPATIONAL CANCER AMONG WOMEN IS INCREASING

Current Estimates of the Attributable Risk

In 1981, Doll and Peto estimated that occupational exposures were responsible for about 4% of cancer among men and 1% among women in the United States [Doll and Peto, 1981]. The impact of occupation varies by socioeconomic status and cancer type, however. Approximately 10% of lung cancer, 30% of bladder cancer, and 30% of leukemia are thought to be occupationally related [Higginson and Muir, 1979]. Among blue-collar workers and in some geographic areas, the proportion of the population participating in hazardous occupations may be higher, leading to a larger attributable risk than the national estimate. It is important to note that even a small attributable risk can result in a large number of cancer cases. If Doll and Peto's attributable risk estimate is correct, approximately 6,600 cases of cancer among women in 2003 in the United States [Jemal et al., 2003] and 7,500 cases among women in the European Union in 1997 [Ferlay et al., 1999] would be related to occupation.

These calculations may not accurately reflect the true cancer burden related to occupation. The statistics are based on research conducted mainly in the 1970s among men from developed countries, primarily in the United States and the United Kingdom. Given the latency of cancer, the relevant years of exposure were up to the 1950s. Few of the populations included women, who were employed infrequently in the large-scale manufacturing workplaces that were the settings for most of this research. These studies largely occurred before the dramatic changes in the participation of women in the workplace or the patterns of employment of women in developing countries. Since then, the proportion of women in the paid workforce, the amounts and types of paid and unpaid labor, the distribution of women by economy sector, the scale of the workplaces, the allowable exposure levels in the workplace, and implementation of workplace exposure controls have changed over time and vary internationally [Stellman and Lucas, 2000]. All of these factors could affect the proportion of cancer due to occupational exposures among women.

Increasing Participation by Women in the Workforce

Doll and Peto's [1981] estimates of the attributable risk of cancer among women due to occupation may not reflect today's risks because of the increasing participation in the workforce by women (Table IV). The percent of women in the United States working outside the home increased from 34% in 1950 to 60% in 1997 [Wagener et al., 1997]. The proportion of a woman's life spent working outside the home has also increased. The once-traditional pattern of leaving the workforce when children are born is not longer the norm. The percent of US women in the labor force with children under age 6 increased from 12% in 1950 to 65% in 1997 [Wagener et al., 1997]. The percent of women with children aged 6 to 17 increased from 29% to 78% between 1950 and 1997. Participation in the labor force has also increased among older women [Wagener et al., 1997].

The employment patterns of women have been changing worldwide as well (Table V). The percent of women in the paid workforce worldwide rose from 31% in 1950 to 45% in 2000, plus an additional 10–20% due to undercounting [Alli, 1999]. Working women in developed countries outside of Eastern Europe rose from 9% in 1970 to 42% in 1990 [United Nations, 1995; Gjerdingen et al., 2000]. A recent prospective cohort study enrolling women in Shanghai, China found 99.6% of women employed (Wong-Ho Chow, personal communication, 2003).

There is serious undercounting of the occupational activities of women in developing country [United Nations, 1995; Stellman and Lucas, 2000]. As much as 35% of the workforce is estimated to be in the informal labor force in countries such as Mali, Honduras, and Burundi (REF) and about 65% of economically active women in Indonesia are in the informal sector [Stellman and Lucas, 2000]. The United Nations estimates that women's unpaid domestic labor accounts for 40% of gross national product worldwide and up to 66% in developing countries [United Nations, 1995].

TABLE IV. Percent of US Women in the Civilian Labor Force, 1950–1997*

Year	Total women	Women with children aged <6 years	Women with children aged 6–17 years
1950	34	12	29
1960	38	17	38
1970	43	25	49
1980	52	44	63
1990	57	60	75
1997	60	65	78

*Wagener et al. [1997], Bureau of Labor Statistics [1998].

Employment by Economic Sector

Today, women are more likely than in the past to work in jobs traditionally held by men that may involve potentially hazardous exposures. For example, between 1960 and 1980, the participation of women in the skilled trades increased fourfold [Quinn et al., 1995] and as mechanics/repairers increased threefold [Bureau of the Census, 1963, 1993] in the United States. With more women working, working longer, and in non-traditional jobs, there is increased potential for sustained exposure to occupational carcinogens.

TABLE V. International Participation of Women in the Workforce

Worldwide [Alli, 1999]	
1950	31%
1975	35%
2000	45%, plus 10–20% undercount
Developed countries [United Nations, 1995]	
1970	9%
1990	42%

The distribution of women's employment by economic sector varies internationally. In the US and the United Kingdom, employment is predominantly in the service industry (69% and 85%, respectively), while manufacturing and agriculture dominate in other parts of the world [Stellman and Lucas, 2000]. Recent epidemiologic studies found that over 90% of women employed in Lodz, Poland, 60% of women employed in Warsaw, Poland, and 60% of women in Shanghai, China work in manufacturing [Wong-Ho Chow, personal communication, 2002] (Table VI). Many manufacturing jobs in developing countries are cottage industries or traditional craft production which may involve little knowledge or control of hazardous exposures [McCann, 1996].

The international variation in the percent of women employed in agriculture is large, ranging from as low as 8% in developed countries to 53% in sub-Saharan Africa (Table VII) [Stellman and Lucas, 2000]. Women produce 60–80% of the basic foodstuffs in sub-Saharan Africa [Alli, 1999; London et al., 2002]. The specific tasks women perform are related to their potential for exposure to potential carcinogens. In developing countries, women are generally weeders, which can involve significant pesticide exposure [Alli, 1999; London et al., 2002]. The amount of pesticides used in developing countries is growing rapidly [Pesticide Action Network-UK, 2002]. Recently, the greatest increased use has occurred in Latin America, particularly for insecticides, which have higher acute toxicity and animal carcinogenicity than herbicides, the class of pesticides which are predominant in developed countries [Pesticide Action Network-UK, 2002].

Industrialization and globalization are strong forces that have changed the employment patterns of women worldwide [Loewenson, 1999]. As countries move from agrarian to industrial, information, and service economies, changes occur in the proportion of women in the paid workforce, the distribution of women by economic sector, and the size of the average workplaces [Alli, 1999]. Many of these new manufacturing facilities in developing countries may have less control of exposures than in developed countries.

TABLE VI. Percent of Employed Women in Manufacturing*

Location	Percent of employed women in manufacturing
Lodz, Poland	>90
Warsaw, Poland	60
Shanghai	60
England	13
United States	12

*From Chow [personal communication] and Stellman and Lucas [2000].

TABLE VII. Percent of Employed Women in Agriculture

Location	Percent of employed women in agriculture
Developed countries	8
Latin America	5
Oceania	21
Northern Africa/West Asia	27
East/Southeast Asia	35
Southern Asia	44
Sub-Saharan Africa	53

From Stellman and Lucas [2000].

Other Social Changes

Other social factors have affected the employment of women around the world, such as wars and repressive governments. For example, in post-Stalinist Russia, women were employed in many occupations that had been traditionally male, taking the place of the many men who had been killed in the World Wars and the Stalinist purges [Bulbulyan et al., 1992; Bulbulyan and Boffetta, 1999]. Currently, similar changes in the jobs held by women are happening in countries affected by the loss of men due to emigration, civil conflict, and disease. These changes affect the opportunity of women to encounter occupational carcinogens.

WHAT IS NEEDED IN FUTURE STUDIES OF OCCUPATIONAL CANCER AMONG WOMEN?

Future studies of occupational cancer should expand their focus on women, avoiding the lack of inclusion of women in past studies. Occupational epidemiologists should conduct high quality, high impact studies that address important scientific questions; increase activities in developing countries; include investigations of newly created industries; improve quantitative exposure assessment; use appropriate referent groups, taking into account healthy worker effect; use advanced molecular epidemiology approaches; conduct studies with sufficient statistical power for the questions under investigation; and increase international, multidisciplinary collaborations (Table VIII). These are relevant to all occupational studies, but some have particular importance for studies of women because of their employment patterns and other factors.

Address Important Scientific Questions

Studies that address important scientific questions should be encouraged. Will the results be important only if an association is found or even if no association is found? Should we conduct studies whose only aim is to replicate well-established associations? Such studies may be useful

TABLE VIII. Recommendations for Future Studies of Occupational Cancer Among Women

- Expand focus on women
- Increase activities in developing countries, where exposures are often greater
- Include newly created industries, whose long-term effects are unknown
- Improve quantitative exposure assessment, considering paid employment, unpaid employment, and non-occupational factors
- Use appropriate referent group, taking into account healthy worker effect
- Use advanced molecular epidemiology approaches, where appropriate, incorporating biomarkers of exposure, intermediate disease states, etiologically relevant subcategories of disease, and susceptibility
- Conduct large studies with sufficient statistical power to detect excess risk, gender differences, and gene—environmental interactions
- Form international, multidisciplinary collaborative teams

for public health planning and for directing or assessing exposure control measures, but otherwise may not be worth the effort and cost to conduct. The resources may be better directed towards uncovering new associations.

Increase Activities in Developing Countries

If future research is to focus on women with meaningful exposures, this will often necessitate studying women in developing countries, where more women work and exposures may be less controlled [Pearce et al., 1994; Boffetta et al., 1995a; Cedillo Becerril et al., 1997]. Good candidate locations are places where there are high exposures, early age at first exposure, interesting concomitant exposures or other unusual employment or disease patterns. Well-designed studies in developing countries may lead to the discovery of new carcinogens and are crucial to identify where better control measures are needed.

Investigate Newly-Created Industries

Special attention should be paid to newly created industries, whose long-term effects are largely unknown. Early initiation of surveillance and research projects can minimize the burden of disease associated with new industries. For example, the growth of the semi-conductor industry in the 1970s and 1980s is a recent phenomenon relative to more traditional manufacturing. The workforce, which includes many women, needs evaluation, particularly as the average latent period for cancer is being met by more workers. A report on 4,388 workers in a semiconductor facility in the United Kingdom found excesses of lung cancer and stomach cancer among women workers, but the number of cases was small and the average length of follow-up was only 12.5 years [McElvenny et al., 2001]. Studies of new industries must not repeat the mistake of focusing mainly on men.

Improve Exposure Assessment

The value of occupational studies is often directly related to the specificity of the exposure assessment. Quantitative and semi-quantitative exposure data reduces the misclassification of exposure typically present in studies based on industry or job title alone, thereby increasing the opportunity to detect true risks [Hoar et al., 1980; Gerin, 1990; Herrick and Stewart, 1991; Stewart, 1993]. Studies reporting elevated risks for a handful of disparate job titles, scattered across the service and various industrial sectors, tend not to be as meaningful as studies with chemical-specific quantitative exposure assessment.

Investigations should consider occupational exposures from paid and unpaid employment, as well as non-occupational factors, such as smoking, alcohol consumption, drug use, and physical activity, that might modify the effects of occupational exposures. In some settings, the unpaid employment and non-occupational factors may be more important than the exposures encountered in formal paid employment settings. Gender differences in occupational training, use of protective equipment, and psychosocial factors could be meaningful [Messing et al., 1993, 1994, 2003; US Department of Labor, 1993; Greenberg and Dement, 1994; Goldenhar and Sweeney, 1996]. In addition to biological differences, research should address broader gender differences, including social constructs, household responsibilities, opportunities, resources, and needs [Messing et al., 2003].

Use Appropriate Referent Group

The healthy worker effect is even greater among women than among men [McMichael, 1976; Herold and Waldron, 1985; Sorlie and Rogot, 1990; Lea et al., 1999], although less for cancer than for other diseases [Gridley et al., 1999]. To a greater extent than among men, women who work outside the home differ from homemakers in terms of age, marital status, family socioeconomic status, fertility, drug use, tobacco use, alcohol consumption, health insurance status, access to medical care, and other factors [McMichael, 1976; Kryston et al., 1983; Herold and Waldron, 1985; Roman et al., 1985; Sorlie and Rogot, 1990; Boffetta et al., 1995b]. In addition, health-related selection out of the workforce is stronger for women than men [Lea et al., 1999]. Therefore, studies comparing working women with unemployed women or with the general population are especially difficult to interpret. Use of employed populations as referent groups may be advisable for some investigations.

Incorporate Molecular Epidemiology Approaches

Future studies of occupational cancer among women as well as men should incorporate state-of-the-art molecular epidemiology approaches where appropriate, including biomarkers of exposure, intermediate disease states, etiologically relevant subcategories of disease, and genetic susceptibility. Studies must include collection of the biospecimens necessary to apply the appropriate approaches to identify and clarify risks and to gain mechanistic insights. Occupational research is an ideal setting to search for gene–environment interactions in cancer epidemiology.

Caution is needed, however, in the interpretation of reported gene–environment interactions. It is theoretically possible, but perhaps rarely plausible, that a putative gene–environment interaction is real while there is no main effect of the exposure. The increasing number of unreplicated findings in the literature suggest we need to be more skeptical than we have been of reports of gene–environment interactions [Caporaso, 2002]. Hirschhorn et al. [2002] reviewed 600 positive associations between common genetic polymorphisms and disease (gene-disease main effects; not gene–environment interactions); of these, 166 associations had been assessed in three or more separate investigations. Only six were "consistently replicated" (defined as having significant associations in 75% or more of the studies assessing the association). Therefore, 90% of reported genetic associations with disease have NOT been replicated. The replication rate for gene–environment interactions is likely to be worse. Studies of gene–environment interactions are important, but are using time, resources, and credibility, so health skepticism and thoughtful interpretation are needed.

Ensure Sufficient Statistical Power

Future studies should be large enough to have sufficient statistical power to detect excess risks, gender differences, and gene–environmental interactions. Very large sample sizes are usually needed for molecular epidemiology studies of potential gene–environment interactions [Garcia-Closas and Lubin, 1999], particularly if the proportion of women exposed is small. For example, even in a large population-based case-control study of cancer and occupation, the analysis of women with a specific occupational exposure and a specific genetic polymorphism will probably be based on extremely small numbers, particularly in developed countries where most women are in service and sales jobs [Bureau of Labor Statistics, 1998]. Larger studies are needed to minimize variability in unstable risk estimates. The search for interactions is useful for understanding mechanisms, even if only a small proportion of the population is affected with the exposure and at-risk genotype and there is not much impact on the overall cancer burden.

In addition, investigators should consider how to replicate their findings. If a population is very large, perhaps it could be split to determine if the findings can be replicated internally. Replication may be possible by conducting similar investigations in multiple, diverse populations. We need to take statistical power seriously and not start small studies that are doomed to be uninformative.

Form International, Multidisciplinary Collaborative Teams

The recommendations to increase attention on women, address important questions, conduct studies in developing countries, study new industries, improve exposure assessment, incorporate molecular epidemiology approaches, ensure sufficient statistical power, and replicate findings translate into the requirement to form international, multidisciplinary, collaborative teams for effective research on many of the pressing issues in occupational epidemiology. Few groups have in-depth expertise in every discipline. Teams with epidemiologists, industrial hygienists, biostatisticians, molecular biologists, geneticists, environmental scientists, toxicologists, behavioral scientists, pathologists, other medical specialists, and community members are needed. Collaborations and consortia are needed to assemble the scientific expertise and large numbers of exposed subjects for meaningful research. Fortunately, the industrialization, globalization, and other social forces that are changing women's work internationally, and possibly increasing their cancer burden, are also making it easier to study women's occupational cancer by facilitating international, multidisciplinary collaborations.

CONCLUSION

To be at the forefront of epidemiology, well-designed studies of important issues with sufficient power are needed. In general, this means that studies need to continue to expand their focus on women, increase activities in developing countries where exposures may be greater, include newly created industries and non-chemical "exposures," such as stress and shiftwork, use sophisticated exposure assessment methods, and, where appropriate, incorporate molecular epidemiologic techniques. Increased international and multidisciplinary collaboration will facilitate studies that yield valid and valuable information. Improved research should lead to the discovery of new carcinogens, identification of where better control measures are needed, and prevention of occupational cancer among women and men.

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